学 位 論 文 要 旨

Cell biology of mechanism of wood formation in trees under different climatic conditions

異なる気候条件下に生育する樹木の木材形成機構の細胞生物学

環境資源共生科学専攻　森林資源物質科学大講座

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Wood is a renewable resource that has been used as a raw material for construction, furniture, pulp and paper, chemicals and fuel. The activity of vascular cambium (cambium) forms wood and increases the radial diameter of tree stem. Cambial activity is controlled through a complex interaction between environmental and internal factors. Thus, climate change might affect cambial activity and, thus, the quantity and quality of wood vary in future. However, the precise process of wood formation through cambial activity under different climatic conditions is not fully understood.

The present cell biological study was designed to identify the factors that regulate cambial activity and xylem differentiation in trees under different climatic conditions. To achieve the purpose, this study was divided into following three Chapters: (1) Induction of cambial reactivation and xylem differentiation under increased temperature on temperate trees, (2) Role of plant hormones on breaking of cambial dormancy and formation of tracheids from late winter to early spring in temperate trees, and (3) Role of climatic factors in regulation of cambial growth on hardwood trees grown in tropical and sub-tropical regions.

In temperate zone, cambial activity ceases in autumn or winter (cambial dormancy) and resumes again (cambial reactivation) in late winter or early spring. Localized heating (20-22℃) in winter or an increase in temperature under natural condition in spring induced cambial reactivation in *Chamaecyparis pisifera* tree. However, *Chamaecyparis* required longer period of heating for cambial reactivation than other conifers. Under natural condition, the timing of cambial reactivation and the threshold value of the daily maximum temperature (13℃) for *Chamaecyparis* were different from other conifers such as *Cryptomeria japonica*. Such differences

were closely related to the cambial sensitivity to temperatures from quiescent to active state. When 1 to 4℃ were added with the actual maximum daily temperatures, the estimated timing of cambial reactivation became earlier, indicating that earlier accumulation of maximum temperature above threshold value changes the timing of cambial reactivation. After formation of a few layers of earlywood tracheids with large diameters and thin walls, tracheids with narrow diameters and thick walls similar to latewood were formed with heating. Moreover, stored starch disappeared from cambial region during formation of tracheids. The shortage of starch which can convert to sugars might be responsible for the formation of latewood tracheids.

Cambial reactivation occurred on heated stems of defoliated (removal of needles and buds) and auxin transport inhibitor NPA treated *Abies homolepis* seedlings, indicating that cambial reactivation is independent of the factors supplied from needles and buds. However, NPA and defoliation treatments delayed or inhibited the formation of earlywood tracheids on heated stems. By contrast, application of natural auxin IAA initiated the formation of earlywood tracheids on heated stem of defoliated seedlings, indicating that continuous supply of auxin to the cambium might be the essential prerequisite for earlywood tracheid formation. However, application of synthetic auxins NAA and 2,4-D with the same amount as IAA showed differences in responses of cambium. NAA did not induce earlywood tracheids, whereas 2,4-D induced a few tracheids and, then, cambial cells de-differentiated into parenchyma cells. The application of another plant hormone gibberellin and gibberellin biosynthesis inhibitor paclobutrazol on heated and non-heated stems induced earlywood tracheids after breaking of dormancy. However, long duration was required to increase cell wall thickness of new tracheids and, finally, less number of earlywood tracheids were formed with paclobutrazol treatment, indicating the role of gibberellin on xylem differentiation during earlywood tracheids formation.

The investigation of cambial activity in tropical trees namely, *Acacia mangium*, *Eucalyptus* sp., *Tectona grandis* and *Ochroma* sp. grown in Indonesia showed that cambium was active in January 2014 during wet season with high precipitation, whereas it was in dormant in absence of precipitation during dry season in October 2015. However, interestingly, in October 2016 during dry season, cambium was active because of unusual frequent precipitation during the dry months from July to October. Moreover, the supply of high irrigation water during hot-summer initiated cambial activity in *Samanea saman* seedlings grown in sub-tropical region, Bangladesh. Therefore, in tropical and sub-tropical trees, the precipitation is one of the most important factors for cambial activity.

In conclusion, an increase in temperature in late winter or early spring is a trigger for cambial reactivation which is independent of the factors supplied from needles and buds in temperate trees. The timing of cambial reactivation varies among species and these differences are closely related to the depth of cambial dormancy. After cambial reactivation with rising temperature, the continuous supply of internal factors such as soluble sugars from stored starch and auxin is required for the initiation of earlywood tracheids. Moreover, gibberellin might be important for increase in the quantity of wood. In tropical and sub-tropical regions, cambial growth is regulated by the precipitation pattern. Thus, the factors that regulate wood formation through controlling cambial activity might differ among different climatic conditions.